

# Industry 5.0:

The True Power of Human and Machine Intelligence

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# Executive Summary

Industry 5.0 marks a transformative evolution in industrial advancement, prioritizing a collaborative framework where human creativity and intelligence synergize with advanced robotics and AI. This new concept shifts focus from the automation and data exchange of Industry 4.0 to a human-centric approach, promising heightened innovation, improved efficiency, and enhanced quality of life through the integration of cutting-edge technologies such as extended reality (XR), artificial intelligence (AI), machine learning (ML), and quantum computing. Historically, the Industrial Revolution has driven significant increases in production and living standards through various technological advancements. Industry 5.0 builds on the foundations laid by Industry 4.0 by addressing its limitations and emphasizing the importance of human involvement and social needs as well as technological progress. Key technologies such as human-robot collaboration, digital twins, big data analytics, and blockchain are essential for realizing the full potential of Industry 5.0. These technologies support the transition to a more human-centric, sustainable, and resilient industrial model, driving new possibilities in sectors like remote assistance, healthcare, education, and manufacturing.

To effectively implement Industry 5.0, strategic actions are necessary. This includes investing in research and development to promote collaboration between industry, academia, and government, as well as implementing reskilling and upskilling programs to prepare the workforce for new demands. Public-private partnerships can promote pilot projects and testbeds to identify best practices and scalable solutions, while infrastructure investments are needed to upgrade digital frameworks, including high-speed internet, IoT networks, and cybersecurity measures. Additionally, developing regulatory frameworks that address ethical, security, and privacy concerns is crucial, alongside efforts to raise community awareness about the benefits and challenges associated with Industry 5.0.

Regionally, North America benefits from strong technological infrastructure and a focus on innovation, though it must address challenges in workforce training and cybersecurity. Ontario is particularly well-positioned to leverage Industry 5.0 through collaboration and workforce development, while Simcoe County can enhance operational efficiency and product quality by concentrating on sectors such as agriculture, manufacturing, and healthcare in partnership with educational institutions. However, there are critical challenges that need to be addressed, including security and privacy concerns during deployment, the need for effective training and ethical considerations in human-robot collaboration, and the significant capital investment required to upgrade traditional facilities and integrate advanced technologies. The transition to Industry 5.0 is therefore essential for achieving a more sustainable, efficient, and human-centric industrial landscape. By focusing on strategic actions and addressing these key challenges, industries can leverage advanced technologies to drive innovation, productivity, and societal progress, ultimately enhancing the quality of life for all.

## Abstract

Industry 5.0 is poised to revolutionize the global industrial landscape by integrating human creativity and intelligence with advanced robotics and AI to create a collaborative, human-centric environment. Unlike Industry 4.0, which focuses on automation and data exchange, Industry 5.0 emphasizes the synergy between humans and machines, driving innovation, efficiency, and improved quality of life. The adoption of technologies such as extended reality (XR), AI, machine learning (ML), and quantum computing will open new possibilities in remote assistance, healthcare, and education. However, this transition faces significant challenges, including security, privacy, and ethical considerations. This paper discusses the evolution from Industry 4.0 to Industry 5.0, highlighting the historical context of industrial revolutions and the technological

advancements that have shaped them. It explores the importance of collaboration between innovation collaborators (educational institutions and private enterprises) and industry partners in leveraging Industry 5.0 enablers and activities. The study also examines the specific perspectives and challenges faced by North America, Ontario, and Simcoe County in adopting Industry 5.0 principles.

By focusing on workforce development, public-private partnerships, infrastructure investment, regulatory frameworks, and community engagement, this paper outlines strategic actions to facilitate the successful integration of Industry 5.0. It emphasizes the need for continuous learning and adaptation to address the dynamic industrial landscape's economic, social, and technological aspects. This comprehensive approach aims to promote sustainable growth, enhance productivity, and drive societal progress towards a more advanced Society 5.0.

## Introduction

The advancement of technology has transformed production methods, a change known as the Industrial Revolution, leading to significant improvements in production, economic growth, and living standards (F. Aslam, 2020), Figure 1. The First Industrial Revolution introduced steam-powered machines in industries like coal and textiles. The Second Revolution, in the late 19th and early 20th centuries, saw the rise of factories using electrical energy and assembly lines, marking the start of the digital age (Nowotarski P., 2017). The Third Revolution advanced iron and steel production and introduced computers, leading to automation in business operations and sectors like logistics and healthcare. During the COVID-19 pandemic, Artificial Intelligence (AI) demonstrated its critical role in automating tasks, reducing human contact, and improving efficiency, with applications ranging from hospital operations to supply chain management, highlighting AI's expanding importance in modern industries.

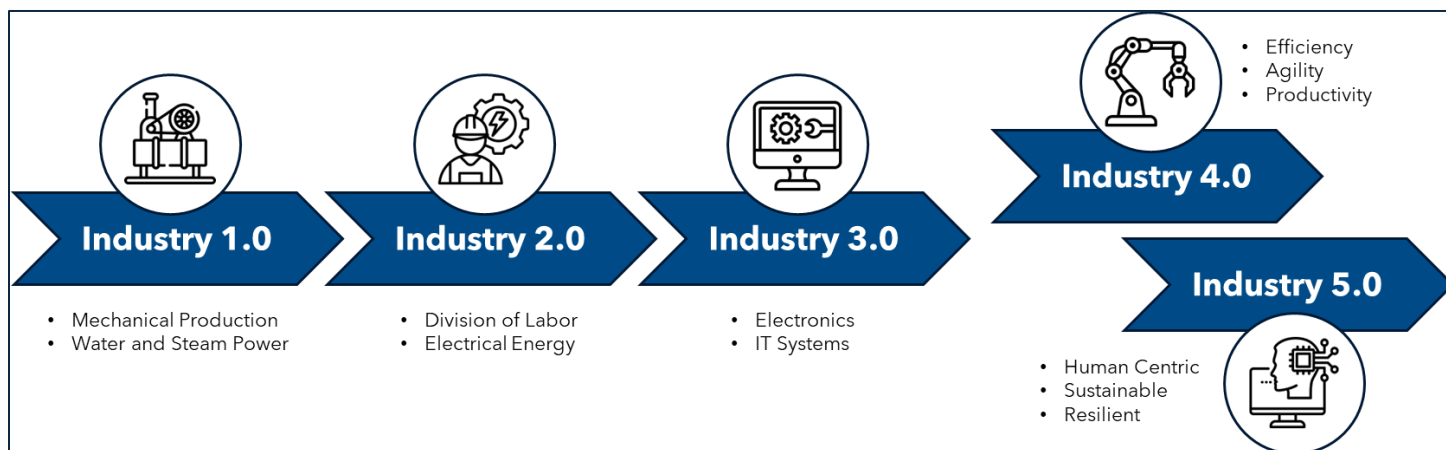


Figure 1: Illustration of Industrial Revolution

Industry 3.0 focused on automating dangerous, dull, and dirty jobs, improving safety, efficiency, and productivity through collaborative robots (cobots). These cobots worked alongside humans, enabling complex tasks and allowing workers to focus on strategic roles (Ashton, 1997). The Fourth Industrial Revolution introduced intelligent machines and AI for low-cost customization and automation, with "lights-out factories" operating autonomously (S. A. T., 2022). As businesses embraced Industry 4.0, Industry 5.0 emerged, emphasizing societal goals, sustainability, and worker well-being. It responds to Industry 4.0's limitations by focusing on human-centered development, addressing workforce concerns about automation,

and promoting harmony between humans and machines, ushering in the "Age of Augmentation" (Longo F, 2020).

## Assessing the Rise of Industry 5.0: Recent Adoption Trends in Canada, Ontario, and Simcoe County

Organizations today face the pressing challenge of balancing economic growth with sustainable practices, particularly in a world that increasingly values human-centric approaches to business. In Canada, as well as globally, companies are struggling with significant environmental challenges that necessitate a shift in how they operate. Canadian organizations have begun to recognize the importance of integrating sustainable practices along with advanced technologies as a means to support a more responsible and progressive business environment that aligns with both social expectations and regulatory requirements (Prasanna, 2019) (Dodds, 2011) (Delannon, 2016) (Matson, 2016).

A qualitative study conducted with fourteen senior managers and executives across various industrial sectors in Canada highlighted the trend toward adopting sustainable practices. This shift is largely driven by the need to adopt with governmental policies and perspectives on environmental responsibility (Ben Youssef, 2023). However, the study also revealed that while there is a growing awareness of sustainability, these practices haven't spread in private industries enough to make a big difference. Key barriers include the substantial infrastructure and capital investments required for such integration, as well as budgetary constraints and the competing strategic priorities that many organizations face. On the other hand, public organizations tend to adopt more standardized and formal frameworks for implementing sustainable strategies, suggesting a more proactive approach to addressing these issues.

The adoption of new technologies, particularly those associated with Industry 5.0, is still in the early stages of understanding and implementation within Canadian organizations. The findings underscore the need for dedicated industrial centers capable of designing and implementing Industry 5.0 technologies and their enablers. Such centers would allow industries to test innovative ideas with minimal financial risk promoting a culture of experimentation and adaptation. While organizations in both public and private sectors have started to embrace trends in hardware, software, process automation, and technology, there remains significant room for improvement. Critical areas include the establishment of comprehensive training and development programs, the adoption of advanced and often costly technologies, and the promotion of a mindset that embraces change across all levels of the organization.

This landscape presents numerous opportunities for Canadian organizations to adapt to the convergence of sustainability and Industry 5.0. Public organizations, with their capacity for standardized approaches, could potentially adapt more rapidly to technological innovations. Conversely, private organizations are encouraged to incorporate training and development programs into their operational frameworks, ensuring that employees are equipped to fully benefit from these initiatives and can more effectively adapt to the evolving landscape of their industries.

A comprehensive research study conducted across various Canadian industries indicated a notable trend in the rapid adoption of new technologies, with 21% of participants representing the manufacturing sector (Chand, 2023). Given that manufacturing alone accounts for approximately 10% of Canada's GDP and 68% of merchandise exports, it becomes increasingly important to focus research efforts on this sector (Chand, 2023). Particular attention should be paid to major sub-sectors such as automotive and aviation, which serve

as the backbone of Canadian manufacturing. Additionally, small and medium-sized enterprises (SMEs) represent a larger proportion of the manufacturing sector in Canada compared to other peer nations, underscoring the need for targeted strategies that support technological integration in these businesses.

Industry experts, including Bedard, emphasize that Canadian manufacturers face significant obstacles in adopting Industry 4.0 technologies and keeping pace with advances associated with Industry 5.0. The most significant challenge identified is the lack of resources, particularly capital investment, which blocks the ability of SMEs to make necessary technological upgrades. As a result, these businesses must carefully evaluate the size and scope of their investments in technology. However, a silver lining exists: some companies may be able to leapfrog the complexities associated with Industry 4.0 and become early adopters of Industry 5.0, thereby conserving capital and positioning themselves competitively in the technological landscape (Bédard-Maltais).

At Georgian College's Research and Innovation Department, the belief is that advanced manufacturing necessitates a transformation in both technical skills and management practices to unlock its full potential. The future workforce in manufacturing will require a diverse skill set that includes data analysts, programmers, and robotics technicians. As such, companies will need to expand their recruitment efforts to attract these specialized workers, while also ensuring that current employees are retrained to meet the demands of new technologies and methodologies. In 2020, Mouser Electronics (Electronics., 2020) examined strategies for Canadian industries to embrace Industry 5.0, highlighting cobots as essential enablers of this transition. These advanced robots, equipped with positional sensors, can detect and respond to the presence of workers, fostering seamless human-robot collaboration. The introduction of lightweight, faster, and more flexible cobots is critical, as their enhanced safety features enable a broader range of human involvement in production processes. The growing interest in cobots has been observed by major players in the automation sector. Well known industrial robotic manufacturers, including ABB, Fanuc, Siemens, and Kuka, as well as specialized firms like Denmark's Universal Robots, have responded by designing and launching new cobot products. A remarkable trend is evident in the rapid growth of global cobot installations, which doubled from around 11,000 in 2017 to 22,000 in 2020. A recent study by BIS Research forecasts that the global cobot market, valued at \$580 million in 2018 to \$9 billion by 2024 (Research, 2024).

In a recent report by Canadian Manufacturers and Exporters (CM&E), several key recommendations were made to enhance the adoption of advanced technologies in Canadian manufacturing (Exporters., 2018). These include:

- Tax Incentives: Introducing a shared federal and provincial 20% refundable manufacturing investment tax credit (ITC).
- Program Reforms: Enhancing the Scientific Research and Experimental Development (SR&ED) program and implementing a complementary patent box regime to incentivize innovation.
- Funding Initiatives: Recapitalizing and extending the Strategic Innovation Fund (SIF) for at least ten more years with a minimum of \$2.5 billion in annual funding to support large capital projects in manufacturing.
- Support for SMEs: Targeted program support for small and medium-sized enterprises (SMEs) to fund technology demonstration tours in collaboration with educational institutions.
- Government Coordination: Increasing collaboration across government levels to remove trade barriers and reduce regulatory burdens.

The report highlights the fact that Canadian manufacturers must accelerate the adoption of Industry 4.0 technologies, such as robotics, IoT, cloud networks, and AI, by 2030, while also exploring advancements

toward Industry 5.0. Recommendations also included adapting recruitment methods for high-skill candidates and enhancing customer service through improved customization and service-oriented business models. As an example, the Canadian construction industry, which contributes about 7% to the GDP, faces challenges in technology adoption, resulting in stops in labour productivity (Bédard-Maltais). 80% of companies in Canada have adopted some form of automation, while less than 50% have fully embraced Industry 4.0 approaches (Exporters., 2018). However, 55% of Canadian manufacturers have not yet invested in advanced manufacturing technologies. Despite of our reputation as a leader in AI, Canada ranked last out of ten countries in its implementation, with only 31% of firms claiming successful AI deployment (Exporters, 2023). As of 2023, Canadian manufacturers have made some progress adopting advanced technologies such as cybersecurity and cloud computing, but our nation still lags much of the world (Exporters., 2018). CME identified four main barriers to technology adoption: 1) difficulties associated with integrating advanced technologies with existing systems, standards, and processes; 2) high purchase costs and uncertain economic return; 3) lack of skilled workers needed to make the most of advanced technologies; and 4) insufficient government financial and/or tax incentives. In Barrie, Simcoe County, the manufacturing sector is a significant employer and is expected to grow by 11.1% in the coming years. While early exploration of Industry 5.0 concepts is underway, more data and analysis are needed to fully understand its potential in the region (Department, 2023).

## Industry 4.0 vs. Industry 5.0: A Shift Towards Human-Centricity

Industry 4.0 marks the digital transformation of manufacturing and production processes, emphasizing automation through cyber-physical systems, the Internet of Things (IoT), and AI. This era, initiated by the German industry, envisions smart factories with minimal human intervention, although recent studies highlight the need for a more human-centric approach (Kagermann, 2011). Longo et al. (Longo, 2019) introduced frameworks such as Digital Twins and Augmented Reality to empower operators, advocating for "smart operators" who enhance adaptability in dynamic environments. On the other hand, Industry 5.0, introduced by the European Commission in 2021 (Breque M, 2021), aims to address social challenges by placing human values at the forefront of industrial processes. It prioritizes employee well-being and sustainable practices, marking a transition to a resilient industry that respects ecological limits (Longo F, 2020). Key technologies like edge computing, collaborative robots, and digital twins continue to play vital roles, but with an emphasis on "Weak Designed AI" to ensure human understanding and management. While Industry 4.0 lays the technological groundwork, Industry 5.0 builds upon it by reintegrating human roles and focusing on broader social and environmental objectives, making it a crucial evolution in the industrial landscape.

## Characteristics of Industry 5.0

Industry 5.0 is defined by three key characteristics: human-centricity, sustainability, and resilience, Figure 2.

**Human-Centricity:** As customized mass production and high-quality demands rise; it becomes clear that human roles cannot be fully replaced by machines. Automation and digitalization require human involvement to enhance system reliability and safety (Xiang T. R. Kong, 2019) (Lu Y, 2021) (Alessandra Papetti, 2020). By integrating human and robotic capabilities, operational efficiency improves, benefiting worker health and safety (Kadir BA, 2021) (Valentina Colla, 2021). This approach shifts from a technology-driven mindset to one that prioritizes human needs, emphasizing the importance of human-centric thinking in industrial systems (He

W, 2017). Smart robots and Human-Centric Explainable AI (HC-XAI) are vital in promoting effective human-machine interactions (Davor Horvatić, 2021). Trust within a human-centric society is crucial for stable communication and operational effectiveness.

**Sustainability:** Sustainability in Industry 5.0 rests on three foundations: economy, environment, and society. Sustainable manufacturing is essential for social health and aligns with the Sustainable Development Goals (SDGs), particularly in "Responsible Consumption and Production" and "Industry, Innovation, and Infrastructure" (Bednar PM, 2020). The vision for sustainable manufacturing emphasizes community-focused resources and designs. Unlike previous industrial revolutions, Industry 5.0 aims for a balanced integration of these three foundations, recognizing the need for economic viability while fostering social and environmental well-being.

**Resilience:** Resilience indicates a system's capability to maintain stability during disruptions, whether from geopolitical changes, natural disasters, or ongoing pressures (Fatima Ezahra Touriki, 2021). Industry 5.0 emphasizes the importance of resilience, both for businesses facing external challenges like market fluctuations and for the broader industrial ecosystem, including national frameworks. This capability is a driving factor behind the rapid shift from Industry 4.0 to Industry 5.0, highlighting the need for adaptability in uncertain environments (S. S. , 2020).

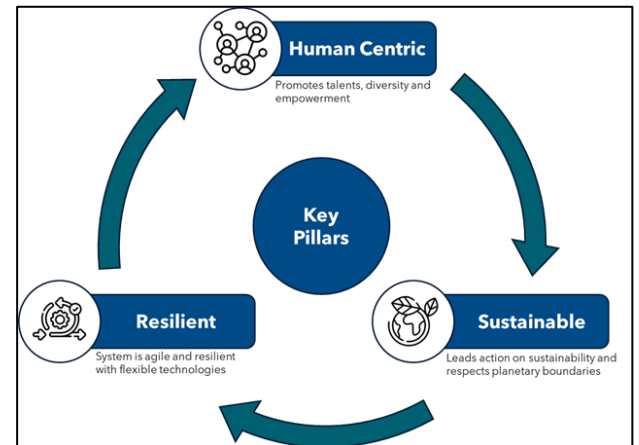


Figure 2: Characteristics of Industry 5.0

## Basis of Industry 5.0

Industry 5.0 represents a transformative vision for the future of manufacturing, emphasizing a people-centered approach, sustainability, and resilience. Its core concept revolves around collaborative intelligence, where human capabilities merge with artificial intelligence (AI) to support innovation in product and service design. This collaboration enhances both human and machine roles: workers train and oversee machines while machines augment workers' cognitive abilities and handle routine tasks, Figure 3.

Key features of Industry 5.0 include:

**Multi-objective Interweaving:** Industry 5.0 aims to achieve diverse goals, including human efficiency, productivity, and meeting customers' individualized needs across various fields like social and ecological domains (Ozdemir V, 2018), smart healthcare (Javaid M. H., 2020), and economics (Javaid M. a., 2020) (Sandra Grabowska, 2022) (Sharma M, 2022). Industry 5.0 will not only promote economic recovery and industrial transformation but also play a significant role in global energy conservation and emission reduction efforts.

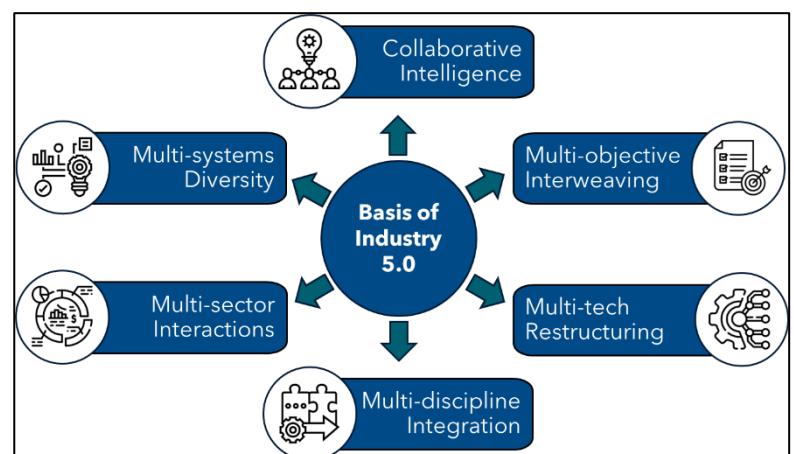


Figure 3: Schematic of the Basis of Industry 5.0

**Multi-technology Restructuring:** Integrating advanced technologies like blockchain and human-robot collaboration to create a value-driven system, moving beyond the technology-centric focus of Industry 4.0, enhancing the collaboration between humans and robots through reorganized smart technologies (Kent MD, 2021).

**Multi-discipline Integration:** Combining knowledge from various fields, including engineering, life sciences, environmental, social sciences, and humanities studies, to tackle complex industrial challenges and redesign manufacturing systems.

**Multi-sector Interactions:** Encouraging dynamic exchanges between industries, society, and the environment to address multifaceted challenges, integrating economic objectives with social and ecological responsibilities. While acknowledging the power of technology to drive industrial revolutions, Industry 5.0 integrates economic goals with social and environmental responsibilities. This includes enhancing workplace safety through new technologies and supporting human-robot collaboration (Sandra Grabowska, 2022).

**Multi-systems Diversity:** Promoting interaction among diverse systems to enhance resilience and adaptability, leveraging concepts from Cyber-Physical Systems to develop new frameworks like Human-Cyber-Physical Systems (Diego G.S. Pivoto, 2021) (Liu, Peng, Wang, Yao, & Liu, 2017) (Gürdür Broo D, 2022).

## An Architecture for Implementing Industry 5.0

Currently, there is limited systematic research on Industry 5.0. Jiewu Leng et al. (Jiewu Leng, 2022) suggested breaking Industry 5.0 into three dimensions, creating a pathway from Industry 5.0 to Society 5.0.

1. Technical Dimension
2. Application dimension
3. Reality Dimension

This pathway illustrates the transition from Industry 5.0 to Society 5.0, Figure 4, emphasizing the vital role of collaboration between innovation collaborators and industry partners. Innovation collaborators provide access to cutting-edge technologies and knowledge, enabling industry partners to leverage Industry 5.0 enablers and activities. The integration of advanced technologies into industry operations drives productivity and sustainability.

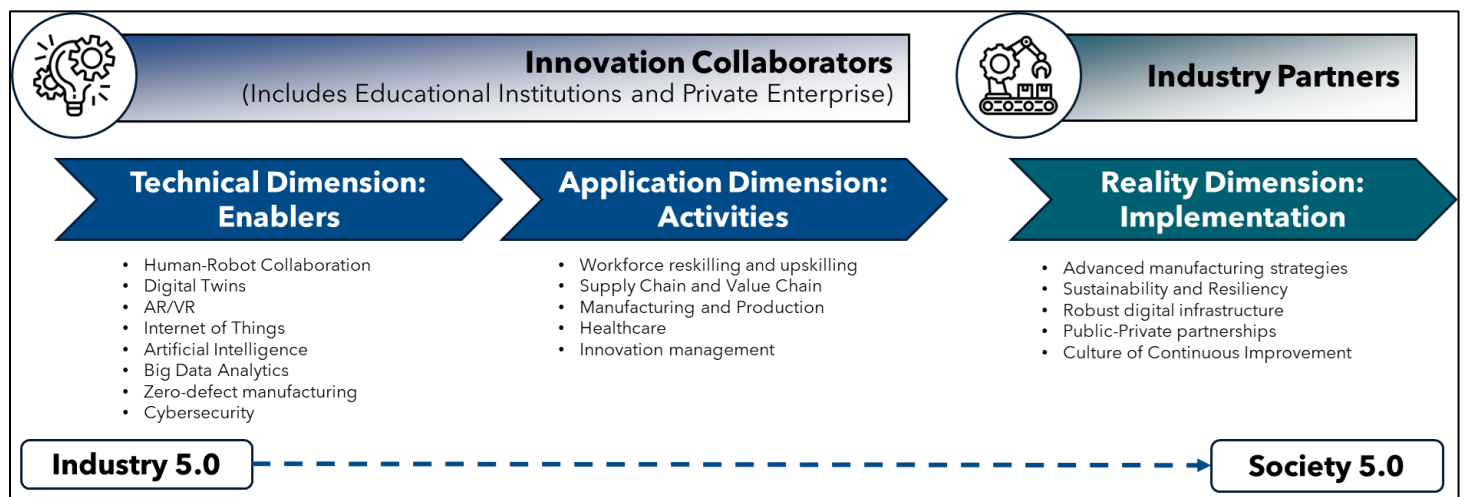


Figure 4: Implementation pathway of Industry 5.0 [68]

## Enablers of Industry 5.0 (Technical Dimension)

Emerging technologies like Health Recovery Solutions, DTs, blockchain, big data, the metaverse, and human factors engineering are integrated with cognitive skills and development concepts to facilitate the flow of advanced knowledge and support a value-driven Industry 5.0 model. Jiewu Leng et al. (Jiewu Leng, 2022) presented a list of keys enabling technologies and techniques essential for realizing Industry 5.0 based on current research, Figure 5. These technological enablers are just the beginning of the transition to Industry 5.0.

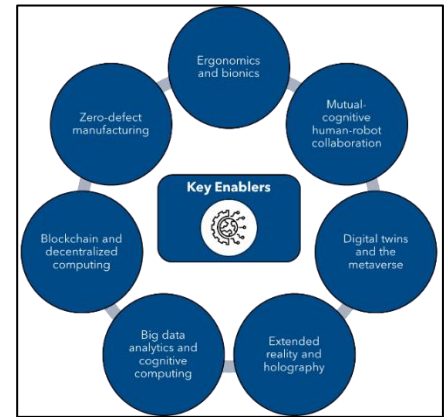


Figure 5: Key enablers for Industry 5.0

## Applications of Industry 5.0 (Application Dimension)

According to Jiewu Leng et al. (Jiewu Leng, 2022), despite the global pandemic causing economic downturns and industries facing urgent recovery needs, Industry 5.0 has yet to gain general recognition. However, significant advancements have been made in new-generation technologies such as information technology, biotechnology, materials science, and renewable energy.

## Implementation Path of Industry 5.0 (Reality Dimension)

From an evolutionary standpoint, implementing Industry 5.0 is a gradual process, not an immediate transition. It requires ongoing alignment with real-world industrial needs and a focus on advancing its tangible benefits. The potential paths for implementing Industry 5.0 include (Jiewu Leng, 2022):

- Developing a global industrial blueprint
- Addressing the dual challenges posed by the COVID-19 pandemic
- Fostering a community with a shared future for humanity

## Enabling Technologies

In the previous section, the enablers of Industry 5.0 were discussed, laying the groundwork for understanding the core technologies driving this new industrial model. Key technologies essential for Industry 5.0 include advancements in human-robot collaboration, digital twins (DTs), big data analytics, and blockchain. These technologies collectively support the transition to a more human-centric, sustainable, and resilient industrial model.

Industry 5.0 encompasses the following six key enabling technologies (Commission, 2020):

1. **Personalized Human-Machine Interaction:** Technologies that seamlessly integrate human and machine capabilities.
2. **Bio-Inspired Technologies and Smart Materials:** Materials embedded with sensors and advanced features, that are designed to be recyclable.
3. **DTs and Simulation:** Tools for modeling entire systems and their interactions.

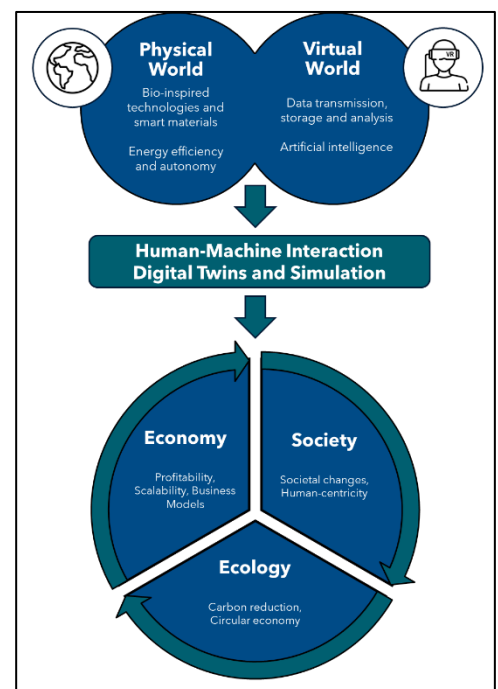


Figure 6: Industry 5.0 goals, based on [82]

4. **Data Management Technologies:** Solutions for efficient data transmission, storage, and analysis, ensuring system interoperability.
5. **AI:** Techniques for identifying causal relationships in complex, dynamic systems to generate actionable insights.
6. **Energy Technologies:** Innovations in energy efficiency, renewable sources, storage, and autonomous systems.

As illustrated, Industry 5.0 is driven by values rather than merely technological advancements, focusing on purposeful technological transformation, Figure 6.

## Future Implementation Challenges

Industry 5.0 aims to enhance manufacturing through cognitive-enabled systems, offering highly customized services. However, it faces significant challenges, including security vulnerabilities, privacy concerns, and ethical implications related to AI. Effective human-machine collaboration necessitates training and practical solutions, ensuring seamless integration between humans and robots.

**Security:** Industry 5.0 must address critical security needs, such as integrity, availability, authentication, and auditing. The integration of AI introduces new security challenges, making trusted execution essential for protecting the integrity of datasets used in machine learning (ML) (N.V. Korneev, 2020). Additionally, secure data sharing for unified learning is necessary, alongside proactive defenses against data theft (Kotianová, 2019) (P. Porambage, 2021) (L. Bilge, 2012) (Y. Siriwardhana, 2021). The emergence of quantum computing could further complicate security measures while potentially simplifying the protection of legacy systems (C. Cheng, 2017).

**Privacy:** Safeguarding intellectual assets and data during transactions is crucial to maintain trust in the cloud manufacturing ecosystem (C. Esposito, 2016). Data exchanged between machines and collaborators must be protected from unauthorized access (L.J. Wells, 2014). There are social concerns about job displacement due to AI, although Industry 5.0 is expected to create new job opportunities. Ethical issues surrounding AI's impact on labor must also be carefully managed (Stahl, 2021). Privacy concerns include protecting human data rights and preventing data theft during cognitive analysis (Pauwels, 2019).

**Human-Robot Collaboration:** The reintroduction of humans along with cobots to enhance personalized product development raises questions about workplace dynamics and the need for adaptation in roles and responsibilities. While cobots handle repetitive tasks, concerns about job displacement and changes in workplace dynamics persist (Sheridan, 2019).

**Scalability:** The ability of systems to adapt to varying workloads is vital. Industry 5.0 must manage the complexity of interconnected systems while ensuring efficient performance tracking and minimal processing delays. This includes leveraging digital twins (DTs) for virtually testing efficiency and productivity (D. Kiran, 2020). AI-powered cobots should manage numerous queries from dynamic cloud and edge servers with minimal delay.

**Skilled Workforce:** A skilled workforce is essential for high-value tasks. Challenges include a shortage of trainers and the need for enhanced training programs, alongside fostering public-private partnerships (D. Paschek) (S. Sanghi, 2012). The educational sector is crucial for helping industries adapt to new technologies, while companies must cultivate an open culture and sustainable recruitment practices.

**Infrastructure and Capital Investment:** Upgrading traditional manufacturing facilities to support advanced technologies requires significant investment. Companies face challenges in enhancing both physical and digital infrastructure, and collaboration with educational institutions can help address funding and resource needs.

**Regulatory Compliance:** Robust regulations are essential for governing the integration of humans and cobots. Specific standards for Industry 5.0 need to be established to address safety, interoperability, and ethical considerations (F. Lima, 2019) (K.A. Demir, 2019). These regulations will facilitate smoother and faster adoption of Industry 5.0 technologies.

## Practical Examples of Industry 5.0

As discussed before, Industry 5.0 hits 4 main areas at first: Manufacturing, healthcare, supply chain and education. In this section some practical examples of Industry 5.0 are provided.

**Example 1:** The Buga Wood Pavilion, also known as the Bundesgartenschau Pavilion, is a wooden structure created through a collaboration between Müllerblaustein Holzbauwerke, KUKA, and the Institute for Computational Design and Construction (Stuttgart, 2019). A robot built this pavilion using 400 timber elements, performing all carpentry tasks such as moving large pieces, assembling them, and applying adhesives. This project demonstrates how robotics and craftsmanship can work together, highlighting human-robot interaction as a core value of Industry 5.0.

**Example 2:** One of the main targets of Industry 5.0 is sustainability. Before Industry 5.0, waste management primarily focused on recycling, reusing, and reducing. However, Industry 5.0 aims to manage waste through industrial upcycling. Repsol, a multi-energy provider, leverages technological advancements to build more sustainable energy models (Repsol, 2020). Repsol employs blockchain, cyber-physical systems, and robotic process automation technologies to enhance security and productivity at its plants, reducing the need for physical presence in dangerous sites through process automation. Additionally, Repsol applies Industry 5.0 principles to improve working methods and environments, both hardware and software, through automation.

**Example 3:** Repsol develops advanced AI projects to optimize industrial processes. The company's first cobot, an autonomous guided vehicle with a load capacity of 100 kg, is designed to perform logistics activities between different plants. These activities include sample distribution between laboratories, waste disposal, and delivery of raw materials from the warehouse. This cobot enables lab virtualization, allowing practitioners to access and manage equipment remotely. This highlights the core value of Industry 5.0: human-robot collaboration.

**Example 4:** The Block Lab is another Industry 5.0 project by Repsol, designed to safely transmit sensitive or critical information using blockchain's immutability and hash indices. The Block Lab streamlines sample management by creating digital equivalents of samples for safety concerns and can effectively manage 10,000 samples per year.

## Final words

Industry 5.0 is poised to transform the global industrial landscape by supporting collaboration between humans and machines, moving beyond the automation focus of Industry 4.0. This model emphasizes human creativity and intelligence as well as advanced robotics and AI, aiming to enhance innovation, efficiency, and quality of life. Key technologies such as extended reality (XR), AI, machine learning, and quantum computing will enable new opportunities in various sectors including healthcare and education. However, the shift to Industry 5.0 presents challenges, notably in security, privacy, and ethics. Unlike the technology-driven nature of Industry 4.0, Industry 5.0 is value-driven, reminding us of essential social needs and responsibilities. It relies on the technological advances of Industry 4.0 while emphasizing the importance of thoughtful decision-making to navigate emerging terms like Industry 4.0+, Industry 4.5, and future iterations. This discussion aims to inspire deeper conversations about these changes, highlighting the need for a clear vision for the future of industry.

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